Renewable and Sustainable Energy Reviews 38 (2014) 439–460

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The challenges and possible solutions of horizontal axis wind turbines as a clean energy solution for the future

Noor A. Ahmed *, Michael Cameron

School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, NSW 2052, Australia

ARTICLE INFO

Article history:
Received 2 July 2013
Received in revised form
19 May 2014
Accepted 18 June 2014

Keywords:
Horizontal axis wind turbine
Wind
Renewable energy

ABSTRACT

This paper presents a review of existing and emerging wind power technologies in light of the evident trends of the industry, and describes the challenges these technologies will face if wind turbines were to become a significant and reliable source of clean energy of the future. Apart from withstanding both the cost pressures against other forms of renewable and non-renewable technologies and the technical and design challenges for efficient and enhanced performance under all weather conditions, a major hurdle that must be overcome is to make the wind farms acceptable to the general public. Although there is now a greater awareness amongst world population about the perils of climate change, the issue of wind turbine generated noise, land use, fauna deaths and visual impacts have to be adequately addressed to ensure continued political and public support for the technology to flourish. These are the viewpoints against which emerging technologies are reviewed and the capacity of some of them to address these issues explored.

Contents

Abbreviations: AWEA, American Wind Energy Association; CCGT, combined cycle gas turbine; CO_2, carbon dioxide; CSG, coal seam gas; CSP, concentrating solar power; °C, degree Celsius (or centigrade); °E, °N, °S, °W, degree east, north, south and west; DK, Danish Kingdom; EIA, energy impact assessment; GW, giga watt; HH, Henry Hub (in relation to gas price); ICOADS, comprehensive ocean-atmosphere data set; IEA, International Energy Authority; kW, kilo watt; LCOE, levelized cost of electricity; LNG, liquefied natural gas; M (or m), meter; m/s, meter per second; MMBtu, million metric british thermal unit; MW, mega watt; MWh, mega watt hour; NBP, national balancing point; NCDC, National Climatic Data Centre; NESDIS, National Environmental Satellite, Data, and Information Service; NOAA, National Oceanic and Atmospheric Administration; PTC, production tax credit; PV, photo voltaic; TFC, total final consumption; UK, United Kingdom; UNEP, United Nations Environmental Program; US, United States

* Corresponding author. Tel.: +61 2 9385 4080; fax: +61 2 9663 1222.
E-mail address: n.ahmed@unsw.edu.au (N.A. Ahmed).

http://dx.doi.org/10.1016/j.rser.2014.06.004
1364-0321/

1. Introduction

With climate change and environmental concerns growing, the need for a greener world with cleaner energy has never been greater. Yet predicting a timeline when, how and with what technologies it will be achieved is shrouded with conflicting claims and controversies. The Rene21 Global Future Report of 2013 [1] paints an overly optimistic picture, while "Tracking Future Energy Progress" report [2] in the same year of 2013 by the International Energy Agency (IEA) appears to suggest that progress towards clean energy had stalled based on the assessment that the cleanness of an average unit of power in the world has remained virtually unchanged over the last 20 years. Greenpeace [3] or Bloomberg New Energy Finance [4] are upbeat about rapid transformation of the economy towards renewables and smart grids while fossil fuel industry and conservative research groups are in complete denial of the very climate change itself and advocate either status-quo or further growth of fossil fuels [5].

It is against this background of the clashes of future visions that we have undertaken this review not to resolve the clash of entrenched visions for future world, but to look objectively to identify some of the challenges that face one of the candidates of renewable power generation, namely wind power, with which the authors have been involved [6–14] and facilitating the development of various test facilities [15–21] and flow diagnostic techniques [22–29] along with conducting flow field investigations [30–44] towards applications of flow control methodologies [45–49] that may provide possible solutions and performance enhancement opportunities. Of these, particular mention may be made of the design of test facilities such as a test rig for investigating rotor dynamic stall [20], design of an anechoic chamber for measurements of wind turbine noise [17], design of a portable rain chamber that can be adapted to existing wind tunnel test facilities [15] to investigate performance under rain; development of flow diagnostic techniques such as Laser Doppler velocimeter [25–28] and multi-hole pressure [22–27,29,30] for complex three-dimensional velocity measurements; the development and validation of the highly loaded theory for wind turbine rotor design [11]; a novel high efficient wind turbine [12] for urban dwellings and innovative applications of aerodynamic principles of flow control for enhanced wind turbine performance and safer performance using exponentially decaying air vortex generators [21,48] requiring minimum energy input, Coanda jet [38] or synthetic jet actuation [45,47] to address the problems of flow separation and control of dynamic stall.

The last two decades have seen phenomenal growth of the wind turbine industry that is evident in the global wind power capacity growth in the 1996–2011 periods as depicted in Fig. 1.

Conventional power generation from coal fired is heavily subsidized by governments around the world to the tune of nearly 8% of total government revenue [51] whereas electricity production from wind power does not. Thus in terms of levelized cost of electricity (LCOE), Wind Power has been at a significant disadvantage. Yet recent data suggests that the cost of electricity from wind power in Australia and many\countries in the world have been falling fast and will continue falling as capacity\increases and technology improves making the Wind Power sector either on par or near parity with conventional power generation sectors [50]. As an example, Bloomberg [52] has shown that under Australia's carbon pricing policy, from newly built facilities, the cost of electricity from a new onshore in Australia is $A80/MWh compared to $A143/MWh for a new coal-fired power station and $A116 for a new gas fired power station. Noting further that wind energy requires no water in its operation, except during maintenance cleaning that does not happen very frequently, whereas other fossil fuel extractions and their usage do require water, a commodity that is essential to sustain life but is fast becoming scarce (Fig. 2). Additionally, wind power doesn't produce pollutants such as nitrous oxide or sulphur dioxide or particulates as coal, and to a lesser extent gas do (see also Fig. 23), and it is forecast by the IEA to make the greatest contribution of all clean energy technologies in coming decades in terms of $C0_2$ reduction (Fig. 3) [50] making wind power an invaluable asset in the quest for a sustainable environment.

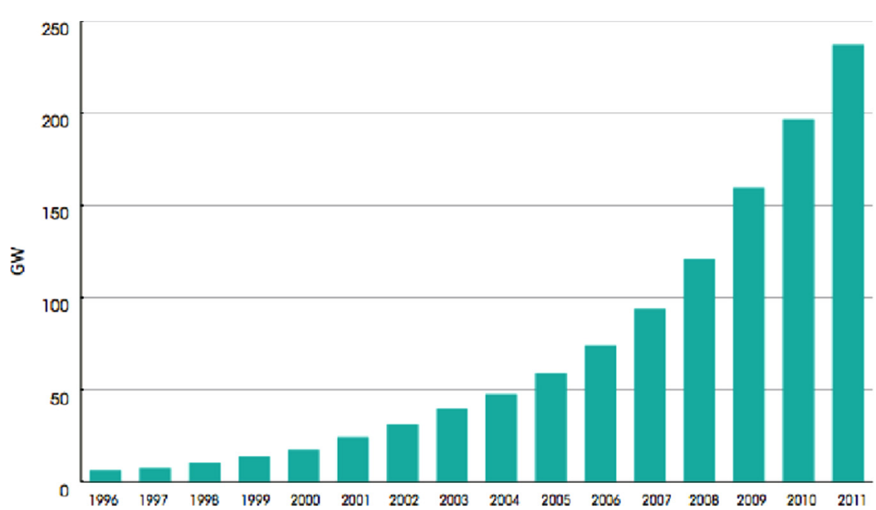

Fig. 1. Annual growth in global wind power capacity up till 2011 (taken from [4]).